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ORIGINAL ARTICLE

Surgeon-specific factors have a larger impact on decision-making for the management of proximal humerus fractures than patient-specific factors: a prospective cohort study

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Background: There is significant variability both in how proximal humerus fractures (PHFs) are treated and the ensuing patient outcomes. The purpose of this study was to investigate which surgeon- and patient-specific factors contribute to decision-making in the treatment of adult PHFs. We hypothesized that orthopedic sub-specialty training creates inherent bias and plays an important role in management algorithms for PHFs.

Methods: We performed a prospective cohort investigation in 2 groups of surgeons—traumatologists (N = 25) and shoulder & elbow/sports surgeons (SES) (N = 26)—and asked them to provide treatment recommendations for 30 distinct clinical cases with standardized radiographic and clinical data. This is a population-based sample of surgeons who take trauma call and treat PHFs with different sub-specializations and practice settings including academic, hospital-employed, and private. Surgeons characterized based on subspecialty (trauma vs. SES), experience level (>10 vs. ≤10-years), and employment type (hospital- vs. non-hospital-employed). Chi-square analyses, logistic mixed-effects modeling, and relative importance analysis were used to evaluate the data.

Results: Of the patient-specific factors, we found that the management of PHFs is largely dependent on initial radiographs obtained. Traumatologists were more likely to offer open reduction internal fixation (ORIF) and less likely to offer arthroplasty: 69% ORIF (traumatologists) vs. 51% ORIF (SES, $P < .001$), 8% arthroplasty (traumatologists) vs. 17% (SES, $P < .001$). Traumatologists were less likely to change from operative (either ORIF or arthroplasty) to non-operative management compared to SES surgeons when presented with additional patient demographic data. Surgeon-specific factors contributed to more than one-half of the variability in decision-making of PHF management while patient-specific factors contributed to about one-third of the variability in decision-making.

Conclusions: As physicians strive to advance the treatment for PHFs and optimize patient outcomes, our findings highlight the complex overlap between surgeon-, fracture-, and patient-specific factors in the final decision-making process.

University of California, Irvine, Institutional Review Board approved this study (HS# 2019-5578; Establishment of Objective Guidelines for Consistent Management and Surgical Treatment of Proximal Humerus Fractures).

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Proximal humerus fractures (PHFs) are common injuries routinely treated by both general and subspecialist orthopedic surgeons. It is estimated that adult PHFs occur at a rate of 6 per 100,000 people in the United States and are the third most common osteoporosis-related type of fracture in the elderly.[10,12] Fracture classification systems are designed to be utilized to aid the understanding and treatment,[1,15-17] with the belief that patient-specific and fracture-specific considerations are critical deciding factors in selecting the best treatment option for patients. Despite this, there remains significant variability in how PHFs are treated, from non-operative management, to open reduction internal fixation (ORIF), to arthroplasty,[2,14,22,30] even with recent literature stating that there is limited improvement in clinical outcomes based on treatment options.[20] Furthermore, meta-analysis of randomized controlled trials of non-operative vs. surgically treated PHF has demonstrated significant variability in patient outcomes, dependent on both fracture type and surgical management technique.[23] Previous attempts have been made to standardize the management of these complex injuries via advanced imaging[7,9,27] or by improving fracture classification systems.[3,26] However, significant differences in management and substantial controversies in treatment algorithms remain, with poor inter- and even intra-observer agreement in PHF management.[19] As such, it is still unclear whether the critical deciding factor(s) in determining optimal fracture management have been completely identified.

While patient-specific factors should logically dictate treatment, variables introduced by surgeon-specific factors may impact treatment approach, a topic that currently remains largely unstudied. Quantification of the influence of these variables is an important opportunity to better understand treatment algorithms as well as help elucidate why PHF management and outcomes remain so variable. While surgeon age and years of training are logical factors to consider, surgeon sub-specialization provides supplementary knowledge and unique surgical emphases. The advent and proliferation of reverse total shoulder arthroplasty (rTSA)[4,5,25] has provided an additional tool in the surgeon's armamentarium when treating PHFs specifically. rTSA utilization has dramatically increased since its introduction to the United States in 2005, specifically with respect to percentage of arthroplasties performed for fracture indications, from 4.5% in 2009 to 67.4% in 2016.[4] Shoulder arthroplasty is a procedure that is routinely performed by orthopedic surgeons who have had additional training in upper extremity reconstruction. Alternatively, orthopedic surgeons who have increased experience in trauma care have developed and advocated surgical techniques that utilize fibular strut grafting[24] or metal cage constructs[13] to improve construct stability. While both groups of orthopedic surgeons regularly treat PHFs, the impact of these differences in surgical education and technical familiarity has not been rigorously studied. The advent of new techniques in surgical management have also resulted in a higher rate of operative intervention despite studies demonstrating equivalent outcomes for many patients managed non-operatively.[20]

The purpose of this study was to identify which surgeon- and patient-specific factors contribute to variability in treatment of adult PHFs. We hypothesized that orthopedic sub-specialty training creates inherent bias for treatment decisions and plays an important role in management algorithms for PHFs. To assess this, we performed a prospective cohort investigation in 2 groups of surgeons who were asked to make treatment recommendations for 30 distinct clinical cases with standardized radiographic and clinical data.

Materials and methods

We obtained university-based institutional review board approval for this prospective cohort study as well as informed consent from participants. The 2 cohorts consisted of 25 fellowship-trained orthopedic trauma surgeons and 26 shoulder & elbow/sports (SES) surgeons, including currently recognized thought-leaders in both cohorts. Additionally, a wide array of surgeons was chosen encompassing academic (29), hospital-employed (15), and private (7) practice settings. All traumatologists performed <5 rTSA annually, while all members of the comparison group (SES) performed >25 rTSA per year. Data from the American Board of Orthopaedic Surgery website was used to determine the number of years of practice after completion of residency training in orthopedic surgery. Single subject testing duration was 45-50 minutes either in-person or via Zoom, during which the tested surgeon was queried by 1 of 2 fellowship-trained authors as to their management of a series of 30 standardized PHF cases (Supplementary Appendix S1) with varying Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) classifications, patient ages, medical co-morbidities, and laborer/non-laborer status. The same

30 cases were reviewed by each surgeon, including ten 11A, nine 11B, and eleven 11C PHFs based on the AO/OTA classification. Each fracture was considered an isolated injury. The surveyor was available throughout testing to answer questions.

Each case began with a presentation of plain radiographs including anterior-posterior (AP), Grashey, and scapular Y views. Subjects were asked to formulate a treatment plan based on radiographs alone before being provided additional patient demographic information. Treatment options included non-operative management, ORIF (including minimally invasive arthroscopic, percutaneous, and nail techniques), and shoulder arthroplasty (including hemiarthroplasty, anatomic total shoulder arthroplasty, and rTSA). After deciding on an initial treatment plan, surgeons were then asked if they would order a computed tomography (CT) scan as part of their decision-making algorithm. Representative CT images were subsequently provided for review in 15 of the 30 cases. In those cases in which CT images were available, surgeons were again asked for their treatment plan (non-operative vs. ORIF vs. arthroplasty) based on the CT imaging provided. There was no CT imaging available in the remaining 15 cases, even if requested by the surgeon. In these cases, the surgeon was directed to the next question regarding treatment recommendations in the context of patient demographics.

Next, surgeon subjects were provided with patient demographic information including the patient's age, comorbidities, and occupation. They were then sequentially asked if changes in these demographic factors resulted in a change in their treatment and their planned postoperative rehabilitation protocol (Supplementary Appendix S2). As an example, in survey question #4, surgeons were asked, "Knowing the patient's age, how would you now treat the patient?" Response options included nonoperative management, ORIF, and arthroplasty. Question #5 subsequently asked if the treatment plan would change based on the presence of "multiple significant medical co-morbidities," while question #6 asked if the plan would change based on the patient's activity level as a manual laborer (with the dominant arm involved). Surgeons were then asked to select their planned postoperative rehabilitation protocol as to when they would allow the patient to begin passive range of motion, active range of motion, and motion against resistance, with options including immediately, 6 weeks postoperatively, and 12 weeks postoperatively. The complete survey questionnaire as well as the case presentations can be found in Supplementary Appendices S1 and S2, respectively.

A chi-square analysis was used to compare differences in initial treatment selection based on sub-specialty training and years of post-training practice, as well as to compare differences in ordering of CT scans and changes in treatment based on each additional piece of information. We then utilized a logistic mixed-effects model with 2 random effects to account for within-surgeon and within-case correlations (equation 1). The primary model outcome was whether a surgeon's final treatment decision was different from the initial management plan (based on x-rays alone) after viewing CT scan images and learning the patient's age (≥60 vs. <60-years) and presence of comorbidities, controlling for surgeon's experience level (>10 vs. ≤10-years), employment type (hospital- vs. non-hospital-employed) and subspecialty (trauma vs. SES). The same model was used to assess the relative importance of each factor[8] in the decision-making algorithm, across all surgeons. Relative importance was reported as a proportion of the total variance explained by all predictors in the model, accounting for collinearity between predictors.

Equation 1.

$$logit(treatment\ plan\ change) = \beta_0 + \beta_1 CT + \beta_2 PatientAge + \beta_3 AnyComorbidities + \beta_4 10orMoreYears + \beta_5 EmploymentLocation + \beta_6 Subspecialty + \upsilon_{surgeon} + \upsilon_{case}, \quad (1)$$

where β represents parameter beta coefficients for fixed effects and υ represent random error terms for surgeon and case.

Results

We considered physician-specific factors including specialty, employment status, and years of experience. Based on radiographs alone, traumatologists chose ORIF more often compared to SES surgeons while SES surgeons chose non-operative management and shoulder arthroplasty more often compared to traumatologists ($P < .001$) (Table I). SES and traumatologists showed no significant difference in their frequency of requests for CTs ($P = .2$) (Table II). For cases in which a CT was available, there was no significant change in treatment plan between traumatologists and SES surgeons ($P = .5$) (Table III). Overall, there was no significant difference between traumatologists and SES surgeons regarding if they changed their treatment based on patient age ($P = .10$) (Table IV). A subgroup analysis demonstrated that for cases with a CT, traumatologists changed their treatment based on patient age for 20% of cases vs. 18% of cases in SES surgeons ($P = .66$), whereas for cases without a CT traumatologists changed their treatment for 10% of cases based on patient age vs. 17% for SES surgeons ($P = .003$). With regards to patient comorbidities (Table V) and patient occupation (manual labor status) (Table VI), traumatologists were less likely to change their treatment compared to SES surgeons for both patient-specific factors ($P < .001$).

Hospital-employed surgeons (N = 15) had similar treatment choices to the non-hospital-employed group (N = 36) ($P = .48$) (Table I) based on radiographs alone, but requested CTs more frequently than non-hospital-employed surgeons ($P < .001$) (Table II). There was no significant change in treatment plan change between hospital- and non-hospital employed surgeons when a CT was available ($P = .08$) (Table III). Overall, hospital-employed surgeons were more likely to change their treatment plan based on patient co-morbidities ($P = .03$) (Table V) and occupation ($P = .003$) (Table VI), but not patient age ($P = .2$) (Table IV), relative to non-hospital-employed surgeons.

Based on radiographs alone, surgeons with >10-years of experience (N = 28) chose non-operative management and shoulder arthroplasty more often than surgeons with ≤10-

Table I Treatment plan between different surgeon subspecialty, type of employment, and yr of experience based on initial radiographs

Initial treatment based on x-ray	Non-operative	ORIF	Arthroplasty	*P* value
Trauma	23%	69%	8%	
SES	32%	51%	17%	<.001
Hospital-employed	30%	58%	12%	
Non-hospital-employed	27%	61%	12%	.48
≤10 yr of experience	25%	64%	11%	
>10 yr of experience	30%	57%	13%	.02

SES, shoulder and elbow/sports surgeons; *ORIF*, offer open reduction internal fixation.

Table II Frequency of CT scan requests between different surgeon subspecialty, type of employment, and yr of experience

Surgeon characteristic	% Requested CT scan	% No CT requested	*P* value
Subspecialty			
Trauma	65%	35%	
SES	70%	30%	.20
Employment location			
Hospital	74%	26%	
Non-hospital	64%	36%	<.01
Yr of experience			
≤10	66%	34%	
>10	69%	31%	.62

CT, computed tomography; *SES*, shoulder and elbow/sports surgeon.

years of experience (N = 23) (*P* = .02) (Table I). Surgeon years of experience had no impact on frequency of requests for CTs (*P* = .62) (Table II) nor on changing their initial treatment plan when presented with CT (*P* = .16) (Table III), patient age (*P* = .57) (Table IV), patient co-morbidities (*P* = .93) (Table V), or patient occupation (*P* = .08) (Table VI).

For cases in which surgeons changed their treatment based on CT (*P* = .06) or patient age (*P* = .51), physician specialty did not impact the ensuing treatment choice (Table VII). For cases in which surgeons changed their treatment in response to patient co-morbidities (*P* = .02) and occupation (*P* < .001), physician specialty strongly influenced treatment choice (Table VIII).

The mixed-effects logistic regression model contained the following variables: presence or absence of CT scan, age ≥60, patient comorbidities, >10-years in practice, hospital-employed, and surgeon subspecialty training.

Table III Change in treatment based on CT scan between different surgeon subspecialty, type of employment, and yr of experience

Surgeon characteristic	% Changed treatment	% No change in treatment	*P* value
Subspecialty			
Trauma	15%	85%	
SES	17%	83%	.5
Employment location			
Hospital	20%	80%	
Non-hospital	14%	86%	.08
Yr of experience			
≤10	18%	82%	
>10	14%	86%	.16

CT, computed tomography; *SES*, shoulder and elbow/sports surgeons.

These variables explained 63.0% of the variance in the model (R^2 = 63%) with the model outcome being whether a surgeon eventually changed their treatment relative to their initial response (Fig. 1). When this 63% variance was normalized to 100%, the relative importance of each variable to the model outcome was as follows: >10-years of experience 27.6%, patient comorbidities 21.5%, physician subspecialty 18.8%, CT 12.0%, age ≥60-years 10.4%, and hospital-employed vs. non-hospital-employed 9.7%.

Discussion

Although PHFs are treated by orthopedic surgeons from diverse sub-specialty backgrounds, controversy remains regarding the most effective treatment option for each individual patient. While ORIF of PHFs with fixed-angle locking constructs was initially met with optimism and remains quite popular, reoperation rates of >30% and poor outcomes have opened the door for increased adoption of alternative treatment options including arthroplasty and non-operative management.[18,20,29] In accordance with previous studies and other fractures,[3,27] this study confirms that the management of PHFs is largely dependent on initial radiographs. For both groups of surgeons, ORIF was the most common treatment choice with a decision to operate in most clinical cases that were presented to either group, despite prior randomized-controlled multicenter data demonstrating equivalent outcomes when comparing operative and non-operative management.[20] While CT scans are frequently utilized for preoperative planning, they had limited influence on altering the specific type of treatment for either group. Surgeon-specific factors and the effect of subspecialty bias have not previously been studied. This study presents valuable data regarding the impact of surgeon-specific variables on treatment decisions for PHFs.

Table IV Change in treatment based on patient age between different surgeon subspecialty, type of employment, and yr of experience

Surgeon characteristic	% Changed treatment	% No change in treatment	*P* value
Subspecialty			
Trauma	15%	85%	
SES	18%	82%	.10
Employment location			
Hospital	18%	82%	
Non-hospital	16%	84%	.20
Yr of experience			
≤10	17%	83%	
>10	16%	84%	.57

SES, shoulder and elbow/sports surgeons.

Table V Change in treatment based on patient co-morbidities between different surgeon subspecialty, type of employment, and yr of experience

Surgeon characteristic	% Changed treatment	% No change in treatment	*P* value
Subspecialty			
Trauma	5%	95%	
SES	15%	85%	<.001
Employment location			
Hospital	7%	93%	
Non-hospital	11%	89%	.03
Yr of experience			
≤10	10%	90%	
>10	10%	90%	.93

SES, shoulder and elbow/sports surgeons.

Table VI Change in treatment based on patient occupation (manual labor status) between different surgeon subspecialty, type of employment, and yr of experience

Surgeon characteristic	% Changed treatment	% No change in treatment	*P* value
Subspecialty			
Trauma	6%	94%	
SES	21%	79%	<.001
Employment location			
Hospital	9%	91%	
Non-hospital	15%	85%	.003
Yr of experience			
≤10	12%	88%	
>10	15%	85%	.08

SES, shoulder and elbow/sports surgeons.

It is important to recognize differences in the patient populations treated by each group of fellowship-trained surgeons. Most patients treated by SES surgeons are selected on an elective basis, with time available to perform a thorough clinical workup including a stringent analysis of the patient's medical co-morbidities, activity levels, patient education, and medical optimization. This may explain why SES surgeons were more likely to change their management decision from operative management to non-operative management based on patient-specific demographic parameters. Additionally, SES surgeons commonly approach PHFs as cold trauma, where patients present in the outpatient clinic setting after being placed in a sling for a period of time. In contrast, patients treated by traumatologists

Table VII The impact of treatment change based on CT imaging and patient age between different surgeon subspecialty

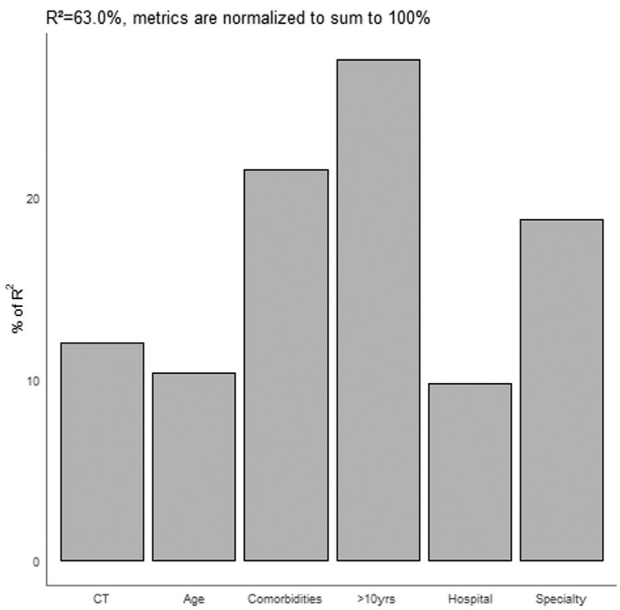
Change based on _______	Subspecialty	% change from ORIF to arthroplasty	*P* value
CT imaging	Trauma	70%	.06
	SES	50%	
Patient age	Trauma	43%	.51
	SES	35%	

CT, computed tomography; *SES*, shoulder and elbow/sports surgeons.

Table VIII The impact of treatment change based on patient co-morbidities and patient occupation (manual labor status) between different surgeon subspecialty

Change based on _______	Subspecialty	% Change from operative (either ORIF or arthroplasty) to nonoperative	*P* value
Patient co-morbidities	Trauma	66%	.02
	SES	80%	
Patient occupation (manual labor status)	Trauma	52%	<.001
	SES	79%	

SES, shoulder and elbow/sports surgeons; *ORIF*, offer open reduction internal fixation.



Model Variable	Relative Importance[#]
>10 years of experience	27.6%
Comorbidities	21.5%
Specialty	18.8%
CT presented	12.0%
Age ≥60	10.4%
Hospital employed	9.7%

Figure 1 Relative importance analysis of variables contributing to the decision-making algorithm of PHF management. # = Relative importance analysis (R^2 = 63%, when normalized to 100%, with relative importance of each variable). *CT*, computed tomography.

often arrive through the emergency department, with trauma and timely operative intervention being unifying characteristics.

Notably, there was no difference in treatment choice for ORIF, non-operative management, or shoulder arthroplasty based on radiographs when comparing hospital- and non-hospital-employed-surgeons, suggesting that hospital vs. non-hospital surgeon employment does not likely play a significant role in the decision-making for management of PHFs. Interestingly, hospital-employed surgeons were more likely to request CT scans compared to non-hospital-employed surgeons. This may reflect decreased logistical challenges in CT approval and scheduling for patients in hospital vs. non-hospital practice environments. Another observed difference was the higher likelihood of non-hospital-employed surgeons to change their treatment based on patient co-morbidities and patient occupation compared to hospital-employed surgeons. This may be a result of the differing patient populations and patient expectations, as well as the nature of the diverse practice environments.

When analyzing years of experience, surgeons with <10-years of experience were more likely to offer ORIF compared to other treatment options, and less likely to offer non-operative management or shoulder arthroplasty compared to surgeons with >10-years of experience based on initial radiographs, suggesting that this surgeon-specific variable may play an important role in the decision-making of PHF management. Years of experience is a plausible surgeon-specific factor contributing to the significant variability in treatment approaches and outcomes of PHFs-based on individual experience with techniques as well as each surgeon's outcomes with different management approaches.

When modeling how variables contributed to the decision-making of managing PHFs, relative importance analysis revealed that, when combined, surgeon-specific factors contributed to more than one-half of the variability in decision-making at 56.1% (>10-years of experience = 27.6%, physician subspecialty = 18.8%, and hospital-employed vs. non-hospital-employed = 9.7%), while variables such as CT scans contributed to 12.0% and patient-specific factors contributed to about one-third of the variability in decision-making at 31.9.% (patient co-morbidities = 21.5% and age ≥60 = 10.4%). This finding suggests that inherent surgeon-related biases and factors may outweigh patient- and fracture-specific considerations when selecting treatment options for patients.

These differences in treatment algorithms and biases between surgeon cohorts are particularly compelling given the expanding literature on complications following PHF management. Specifically, the Delphi multicenter randomized controlled trial recently analyzed 2-year follow-up of OTA/AO type-B2 or C2 PHFs treated with either rTSA or ORIF. Authors noted a significantly better average Constant score of 68 points in those patients treated with rTSA (95% CI, 63.7-72.4) compared to 54.6 points for the ORIF group (95% CI, 48.5-60.7), with an even larger difference (18.7 points) noted when type-C2 fractures were considered in isolation.[6] On the other hand, after controlling for confounding variables in a large German insurance dataset, Köppe et al discovered a higher risk for major adverse in-hospital complications (including myocardial infarction, stroke and death) in patients with PHFs treated with acute rTSA (odds ratio [OR] 1.4) compared to ORIF (OR 1.13).[11] Thus, rather than a single solution, these findings point to the fact that individual outcomes of PHFs are generated from the complex overlap between surgeon-, fracture-, and patient-specific factors, and must be uniquely considered and optimized.

The variables examined in this study explained 63% of the model variance in surgical decision-making, suggesting that there are other factors that explain the remaining 37% that were not captured in this study. While it is difficult to capture every possible variable that goes into management decisions for PHF, we chose those factors that many physicians and surgeons consider most clinically relevant and believe that this study adds valuable insight into many of the factors currently influencing treatment decisions in these complex injuries. This work has several limitations. Although cases were frequently discussed during individual data collection (review of cases), specific questions were not tailored to determine if the traumatologist or SES surgeon would discuss the case with their colleagues, removing the possibility for more collaborative approaches and decision-making. Additionally, all the PHFs presented in our survey were considered as isolated injuries instead of as a polytraumatized patient, which could further influence management decisions. Lastly, we acknowledge that in performing multiple comparisons during our chi-square analyses, the statistical significance of results associated with these comparisons are more difficult to interpret. While we could have narrowed the number of comparisons performed in an effort to improve the statistical strength of these secondary outcomes, we felt that it was more important to include a larger number of variables that might explain some of the variation in decision-making in an effort to highlight or suggest areas of potential focus for future studies. As such, a correction for multiple comparisons was not performed.

Some of the discussed intricacies in decision-making are currently being elucidated through the development and testing of defined management pathways based on fracture pattern and patient demographic characteristics. By identifying set criteria to guide care and apply a standardized algorithm for treatment in elderly PHFs (based on fracture characteristics), Rikli et al reported reduced complication rates and higher rates of post-injury self-dependence in their population.[21] Similar "pathways" have reported success by other groups as well. Using a complex decision-making algorithm incorporating patient age and activity requirements, bone quality (deltoid tuberosity index), fracture classification/displacement, and rotator cuff function, Spross et al recently noted significantly improved outcomes (Constant, EuroQol, Subjective Shoulder Value) and reduced complication and revision rates at 1 year follow-up of PHFs treated at their institution.[28] Such methodologies are the first step toward attempting to improve treatment algorithms, but at this time significant limitations remain with respect to consideration of more complete patient demographic characteristics, as well as fracture classification, and longer-term follow-up.

Conclusions

To improve outcomes in PHFs, further efforts are required to better understand variability in treatment decisions for these complex injuries. We have provided the first data elucidating the importance of surgeon-specific factors in the management of PHFs, creating a foundation for future educational opportunities and progress.

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Supplementary Data

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